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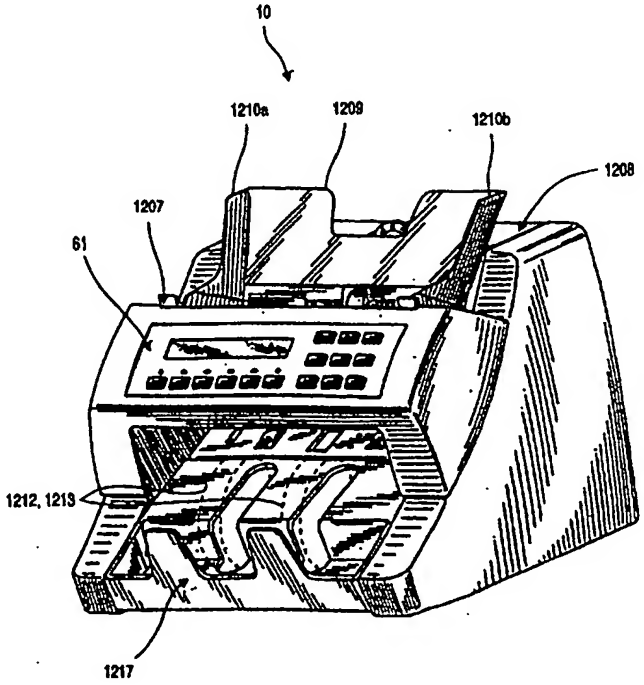
(57) Abstract

A currency discriminating apparatus comprising an input receptacle (2204) for receiving a stack of currency bills and a transport mechanism for transporting the bills, one at a time, past a discriminating unit (2206) to at least one output receptacle (1217). Each of the bills has a denomination associated therewith. The discriminating unit discriminates the denomination of the currency bills using a plurality of magnetoresistive sensors (364, 366, 374). Alternatively, a currency evaluation system that discriminates and authenticates bills based on a plurality of retrieved characteristics. Alternatively, a currency evaluation system discriminating and sorting bills based on series.



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METHOD AND APPARATUS FOR DOCUMENT IDENTIFICATION

SUMMARY OF THE INVENTION

Briefly, according to one embodiment a method and apparatus for denominating and authenticating a currency bill as belonging to one of a plurality of recognizable denominations is provided. According to one embodiment apparatus comprises an input receptacle for receiving a stack of currency bills, each of the bills having a denomination associated therewith. The apparatus also comprises a transport mechanism for transporting said bills, one at a time, past a discriminating unit to at least one output receptacle. The discriminating unit discriminates the denomination of the currency bills. The discriminating unit according to one embodiment comprises a plurality of magnetoresistive sensors.

According to another embodiment, methods and apparatuses are provided for discriminating and authenticating currency bills based on a variety of characteristic information. A plurality of characteristic information is utilized in various combinations to discriminate and/or authenticate bills. For example, a method comprises the steps of retrieving first and second characteristic information from a currency bill and denominating the currency bill a first time as belonging to one of a plurality of recognizable denominations using the first characteristic information. This is accomplished by comparing the retrieved first characteristic information to master first characteristic information associated with each of the plurality of recognizable denominations. Then the currency bill is authenticated by comparing the retrieved second characteristic information to master second characteristic information associated only with the denomination determined by the first denominating step. The bill is rejected if the retrieved second characteristic information does not sufficiently match the master characteristic information associated with the denomination determined by the first denominating step. Otherwise, the bill is denominated a second time if the retrieved second characteristic information sufficiently matches the master characteristic information associated with the denomination determined by the first denominating step by comparing the retrieved second characteristic information to

master second characteristic information associated with each of the plurality of recognizable denominations and determining the denomination of the currency bill to be the denomination associated with the master second characteristic information which most closely agrees with the retrieved second characteristic information. The bill is accepted if the denomination as determined during the second denominating step matches the denomination as determined during the first denominating step. Otherwise, the bill is rejected if the denomination as determined during the second denominating step does not match the denomination as determined during the first denominating step.

Additionally methods and apparatuses are provided for discriminating between and sorting currency bills of different series. For example, the operator of a device having one embodiment of the present invention may designate 1996-series $100 bills to be off-sorted from a stack of U.S. currency bills having a plurality of series-types (e.g., 1996- series U.S. bills and one or more pre-1996 series U.S. bills). When a stack of currency bills is subsequently processed by the currency discriminator, the discriminator proceeds to process all bills in the stack until it encounters the first 1996-series $100 bill. The discriminator then halts operation with the first 1996-series $100 bill being the last bill deposited in the output receptacle of the discriminator. The operator may then remove all the bills in the output receptacle and separate the 1996-series $100 bill from the other bills. The currency discriminator may restart automatically when all the bills in the output receptacle are removed or alternatively, the discriminator may be designed to require the selection of a continuation key. The discriminator then continues to process the remaining bills until it encounters the first non-1996-series $100 bill. Upon encountering the first non-1996-series $100 bill, the discriminator halts operation with the non-1996-series $100 bill being the last bill deposited in the output receptacle. The operator may then remove all the bills in the output receptacle, separate the non-1996-series $100 bill from the preceding 1996-series $100 bills, and place the bills in appropriate stacks. The discriminator then proceeds processing the remaining bills, now halting upon encountering the first 1996-series $100 bill. The operation proceeds as above with the discriminator toggling between halting upon detecting the first bill not of the designated series and the first

bill of the designated series. In this way, the operator may conveniently separate a designated series from bills having a plurality of series. Likewise the above operation may be repeated with the remaining bills to sort out a different series of bills. The above sorting operation is particularly suited for sorting bills in a stack wherein like series bills are grouped together.

The above sorting operation is particularly useful when employed with a currency discriminator having a single output receptacle. Nonetheless, the above sorting operation may be performed on multi-output receptacle discriminators as well, e.g., in a two output pocket discriminator wherein one pocket is dedicated to a specific purpose such as collecting suspect or unrecognized documents.

Alternatively, in a multi-output receptacle discriminator, bills of a designated series are delivered to a first output receptacle and bills of one or more non-designated series are delivered to a second output receptacle. Alternatively, in a multi-output receptacle discriminator, bills of different series are delivered to different output receptacles, each output receptacle receiving bills of a specified series or a specified series and denomination.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and advantages of the invention will become apparent upon reading the following detailed description in conjunction with the drawings in which:

FIG. 1 is a perspective view of a currency scanning and counting machine embodying the present invention;

FIG. 2a is a functional block diagram illustrating another embodiment of a document authenticator and discriminator according to the present invention;

FIG. 2b is a functional block diagram illustrating another embodiment of a document authenticator and discriminator according to the present invention;

FIG. 3 is a top view of a bill and size determining sensors according to one embodiment of the present invention;

FIG. 4 is a side elevation of a multiple scanhead arrangement according to one embodiment of the present invention;

FIG. 5 is a side elevation of a multiple scanhead arrangement according to another embodiment of the present invention;

FIG. 6a is a side view of one embodiment of a document authenticating system according to the present invention;

FIG. 6b is a top view of the embodiment of FIG. 6a along the direction 18B;

FIG. 6c is a top view of the embodiment of FIG. 6a along the direction 18C;

FIG. 7 is a top view of thread sensors of a document discriminating/authenticating system;

FIGs. 8a and 8b are top views of U.S. currency illustrating the location of various magnetic features;

FIGs. 9a and 9b are top views of U.S. currency illustrating various scanning areas according to an embodiment;

FIGs. 10a-10f are tops views of sensor arrangements according to several embodiments of the present invention;

FIG. 11 is a top view of a sensor arrangement according to an embodiment of the present invention;

FIG. 12 is a flowchart illustrating the steps performed in optically determining the denomination of a bill;

FIG. 13 is a flowchart illustrating the steps performed in determining the denomination of a bill based on the location of a security thread;

FIG. 14 is a flowchart illustrating the steps performed in determining the denomination of a bill based on the fluorescent color of a security thread;

FIG. 15 is a flowchart illustrating the steps performed in determining the denomination of a bill based on the location and fluorescent color of a security thread;

FIG. 16 is a flowchart illustrating the steps performed in magnetically determining the denomination of a bill;

FIG. 17 is a flowchart illustrating the steps performed in optically denominating a bill and authenticating the bill based on thread location and/or color information;

FIG. 18 is a flowchart illustrating the steps performed in denominating a bill based on thread location and/or color information and optically authenticating the bill;

FIG. 19 is a flowchart illustrating the steps performed in optically denominating a bill and magnetically authenticating the bill;

FIG. 20 is a flowchart illustrating the steps performed in magnetically denominating a bill and optically authenticating the bill;

FIG. 21 is a flowchart illustrating the steps performed in denominating a bill both optically and based on thread location and/or color information;

FIG. 22 is a flowchart illustrating the steps performed in denominating a bill both optically and magnetically;

FIG. 23 is a flowchart illustrating the steps performed in denominating a bill both magnetically and based on thread location and/or color information;

FIG. 24 is a flowchart illustrating the steps performed in denominating a bill optically, based on thread location and/or color information, and magnetically;

FIG. 25 is a flowchart illustrating the steps performed in a method whereby a bill is denominated based on a first characteristic, then authenticated based on a second characteristic, and if the bill is authenticated, then the bill is denominated again based on the second characteristic;

FIGs. 26-29 are flowcharts illustrating the steps performed in methods whereby a bill is denominated based on a first characteristic, then authenticated based on a second characteristic, and if the bill fails the authentication test, then the bill is denominated again based on the second characteristic;

FIGs. 30-31 are flowcharts illustrating the steps performed in methods whereby a bill is denominated based on a first characteristic, then authenticated based on a second characteristic, and if the bill is authenticated, then the bill is denominated again based on the second characteristic;

FIGs. 32 and 33 are flowcharts illustrating methods where for a bill to be accepted it is first denominated utilizing first characteristic information, then authenticated using second characteristic information, and finally authenticated again using third characteristic information;

FIG. 34 is a flowchart illustrating a method where for a bill to be accepted it is first denominated utilizing first characteristic information, then authenticated using second characteristic information, then denominated using the second characteristic information, and finally authenticated using third characteristic information; and

FIG. 35 is a flow chart illustrating the sequential procedure involved in a sorting operation according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

While the embodiments below entail the scanning of currency bills, the system of the present invention is applicable to other documents as well. For example, the system of the present invention may be employed in conjunction with stock certificates, bonds, and postage and food stamps.

FIGs. 1 depicts a currency scanner having a single output receptacle 1217. FIGs. 2a-2b depict currency scanners having multiple output receptacles. The discriminator systems 2202, 2203 comprise input receptacles 2204, 2204' for receiving stacks of currency bills. Transport mechanisms defining transport paths (as represented by arrows M and M') transport the bills in the input receptacles, one at a time, past one or more sensors of an authenticating and discriminating units 2206, 2206'. Bills are then transported to one of a plurality of output receptacles 2208 (arrow N) or 2208', 2208" (arrows N', N"). Alternatively, in the embodiment depicted in FIG. 1, all bills are transported to a single output receptacle.

The discrimination systems of FIGs. 1-2 and those described below may process bills at speeds of the order of 800 to 1500 bills per minute, including speeds in excess of 800 and 1000 bills per minute according to various embodiments.

The authenticating and discriminating units may be designed to detect a variety of characteristic information from currency bills examples of which are described in more detail below. The authenticating and discriminating units may employ a variety of detection means such as magnetic, optical, electrical conductivity, and capacitive sensors. Use of such sensors is discussed in more detail below. For example, scanheads may employ a magnetoresistive sensor or a plurality of such sensors including an array of such sensors. Such a sensor or sensors may, for example, be used to detect magnetic flux. Additionally, one example of a sensor for denominating bills is the optical scanhead and scanning system described in detail in U.S. Patent No. 5,295,196. This system employs an optical scanhead to optically scan a segment of passing bills and thereby generate scanned reflectance patterns. These scanned patterns are compared to stored master patterns to determine the denomination of bills. The

system can conveniently be programmed to set a flag when a scanned pattern does not correspond to any of the master patterns. The identification of such a condition can be used to stop the bill transport drive motor for the mechanism. Since the optical encoder is tied to the rotational movement of the drive motor, synchronism can be maintained between pre- and post-stop conditions. Additionally, a bill meeting or failing to meet some other criteria, such as being identified to be a suspect bill, may be flagged in a similar manner by stopping the transport mechanism.

In one embodiment, where the authenticating and discriminating unit determines that a bill is a fake, the flagged bill is routed to a separate one of the output receptacles. The operation of the discriminator may or may not then be suspended. When a bill is not determined to be fake but for some reason the authenticating and discriminating unit 2206 is not able to identify the denomination of the bill, the no call bill may be transported one of the output receptacles. In one embodiment, no call bills are transported to a specific one of the output receptacles. In another embodiment, no calls are not delivered to a special separate output receptacle. The operation of the discriminator may or may not then be suspended. For example, in a two output pocket discriminator such as that of FIG. 2b, all bills may be transported to the same output receptacle regardless of whether they are determined to be suspect, no call, or properly identified. In this example, the operation of the discriminator may be suspended and an appropriate message displayed when a suspect or no call bill is encountered. Alternatively, suspect bills may be delivered to one of the output receptacles (i.e., a reject receptacle) and no calls and identified bills may be sent to the other output receptacle. In this example, the operation of the discriminator need not be suspended when a suspect bill is encountered but may be suspended when a no call bill is encountered. In another embodiment, no call bills are delivered to an output receptacle separate from the one or more output receptacles receiving identified bills. The operation of the discriminator need not be suspended until all the bills placed in the input receptacle have been processed.

If the operation is suspended at the time the no call bill is detected (or a bill is flagged based on some other criteria) and the operator determines that the no call bill (or other kind of flagged bill) is acceptable, the operator returns the bill to the output

receptacle from which it was removed (if it was removed) and selects a selection element (not shown) corresponding to the denomination of the flagged bill. Appropriate counters (not shown) are incremented, the discriminator system 2202, 2203 resumes operation. On the other hand, if the operator determines that the flagged bill is unacceptable, the operator removes the bill without replacement form the output receptacle and selects a continuation element (not shown). The discriminator system 2203 resumes operation without incrementing the counters associated with the various denomination and/or the total value counters.

Alternatively, the operation of the discriminator need not be suspended when a no call is encountered but may be suspended when a suspect bill is detected so that the operator may remove any suspect bills from the discriminator. The value of any no call bills may then be added to the appropriate counters after the stack of bills has been processed through a reconciliation process. In an alternate embodiment, suspect and no call bills may be delivered to a specific one of the two output receptacles (i.e., a reject receptacle) and identified bills may be sent to the other output receptacle. Additionally, according to this embodiment, the operation of the discriminator may be suspended and an appropriate message displayed when a suspect or no call bill is encountered.

The authenticating and discriminating units described above may be employ sensors on one or both sides of the transport path so as to permit retrieval of characteristic information from one or both sides of passing bills. Likewise, certain sensors may be placed on one side of the transport path and other sensors may be placed on the opposite side. Still other sensors may be placed on both sides. Likewise for discrimination systems employing multiple scanheads or sensors on a given side of the bill transport path may employ a plurality of laterally displaced scanheads or sensors. These systems may be used, for example, to accommodate bills of non-uniform size and/or color.

To accommodate currencies having a variety of sizes, sensors may be added to determine the size of a bill to be scanned. For example, these sensors may be placed upstream of the scanheads to be described below. One embodiment of size determining sensors is illustrated in FIG. 3. Two leading/trailing edge sensors 62

detect the leading and trailing edges of a bill 64 as it passing along the transport path. These sensors in conjunction with an encoder may be used to determine the dimension of the bill along a direction parallel to the scan direction which in FIG. 3 is the narrow dimension (or width) of the bill 64. Additionally, two side edge sensors 66 are used to detect the dimension of a bill 64 transverse to the scan direction which in FIG. 3 is the wide dimension (or length) of the bill 64. While the sensors 62 and 66 of FIG. 3 are optical sensors, any means of determining the size of a bill may be employed. Once the size of a bill is determined, the potential identity of the bill is limited to those bills having the same size. Accordingly, the area to be scanned can be tailored to the area or areas best suited for identifying the denomination and country of origin of a bill having the measured dimensions.

To accommodate scanning in areas other than the central portion of a bill, multiple scanheads may be positioned next to each other. One embodiment of such a multiple scanhead system is depicted in FIG. 4. Multiple scanheads 72a-c and 72d-f are positioned next to each other along a direction lateral to the direction of bill movement. Such a system permits a bill 74 to be scanned along different segments. Multiple scanheads 72a-f are arranged on each side of the transport path, thus permitting both sides of a bill 74 to be scanned. Two-sided scanning may be used to permit bills to be fed into a currency discrimination system according to the present invention with either side face up. Master patterns generated by scanning genuine bills may be stored for segments on one or both sides. In the case where master patterns are stored from the scanning of only one side of a genuine bill, the patterns retrieved by scanning both sides of a bill under test may be compared to a master set of single-sided master patterns. In such a case, a pattern retrieved from one side of a bill under test should match one of the stored master patterns, while a pattern retrieved from the other side of the bill under test should not match one of the master patterns. Alternatively, master patterns may be stored for both sides of genuine bills. In such a two-sided system, a pattern retrieved by scanning one side of a bill under test should match with one of the master patterns of one side (Match 1) and a pattern retrieved from scanning the opposite side of a bill under test should match the master pattern associated with the opposite side of a genuine bill identified by Match 1.

Alternatively, in situations where the face orientation of a bill (i.e., whether a bill is "face up" or "face down") may be determined prior to or during characteristic pattern scanning, the number of comparisons may be reduced by limiting comparisons to patterns corresponding to the same side of a bill. That is, for example, when it is known that a bill is "face up", scanned patterns associated with scanheads above the transport path need only be compared to master patterns generated by scanning the "face" of genuine bills. The face orientation may be determinable in some situations by sensing the color of the surfaces of a bill. The implementation of color sensing is discussed in more detailed below.

According to the embodiment of FIG. 4, the bill transport mechanism operates in such a fashion that the central area C of a bill 74 is transported between central scanheads 72b and 72e. Scanheads 72a and 72c and likewise scanheads 72d and 72f are displaced the same distance from central scanheads 72b and 72e, respectively. By symmetrically arranging the scanheads about the central region of a bill, a bill may be scanned in either direction, e.g., top edge first (forward direction) or bottom edge first (reverse direction). Master patterns may be stored from the scanning of genuine bills in both the forward and reverse directions. While a symmetrical arrangement is preferred, it is not essential provided appropriate master patterns are stored for a non-symmetrical system. While FIG. 4 illustrates a system having three scanheads per side, any number of scanheads per side may be utilized. Likewise, it is not necessary that there be a scanhead positioned over the central region of a bill. For example, FIG. 5 illustrates another embodiment of the present invention permitting scanning or characteristic information retrieval from other locations.

In addition to size and scanned characteristic patterns, color may also be used to discriminate bills. For example, while all U.S. bills are printed in the same colors, e.g., a green side and a black side, bills from other countries often vary in color with the denomination of the bill. For example, a German 50 deutsche mark bill-type is brown in color while a German 100 deutsche mark bill-type is blue in color. Alternatively, color detection may be used to determine the face orientation of a bill, such as where the color of each side of a bill varies. For example, color detection may be used to determine the face orientation of U.S. bills by detecting whether or not the

"green" side of a U.S. bill is facing upwards. Separate color sensors may be added upstream of the scanheads described above. According to such an embodiment, color information may be used in addition to size information to preliminarily identify a bill. Likewise, color information may be used to determine the face orientation of a bill which determination may be used to select upper or lower scanheads for scanning a bill accordingly or compare scanned patterns retrieved from upper scanheads with a set of master patterns generated by scanning a corresponding face while the scanned patterns retrieved from the lower scanheads are compared with a set of master patterns generated by scanning an opposing face. Alternatively, color sensing may be incorporated into the scanheads described above. Such color sensing may be achieved by, for example, incorporating color filters, colored light sources, and/or dichroic beamsplitters into the currency discrimination system of the present invention. Various color information acquisition techniques are described in U.S. Patent Nos. 4,841,358; 4,658,289; 4,716,456; 4,825,246; and 4,992,860.

While some of the embodiments discussed above entailed a system capable of identifying a plurality of bill-types, the system may be adapted to identify a bill under test as either belonging to a specific bill-type or not. For example, the system may be adapted to store master information associated with only a single bill-type such as a United Kingdom 5 pound bill. Such a system would identify bills under test which were United Kingdom 5 pound bills and would reject all other bill-types.

The scanheads of the present invention may be incorporated into a document identification system capable of identifying a variety of documents. For example, the system may be designed to accommodate a number of currencies from different countries.

Retrieved characteristic information can include reflected light properties such as reflected light intensity characteristics, light transmissivity properties, various magnetic properties of a bill, the presence of a security thread embedded within a bill, the color of a bill, the thickness or other dimension of a bill, etc. With regard to optical sensing, a variety of currency characteristics can be measured such as detection of density (U.S. Pat. No. 4,381,447), color (U.S. Pat. Nos. 4,490,846; 3,496,370; 3,480,785), size including length and width, thickness (U.S. Pat. No. 4,255,651), the

presence of a security thread (U.S. Pat. No. 5,151,607) and holes (U.S. Pat. No. 4,381,447), and patterns of reflectance and transmission (U.S. Pat. No. 3,496,370; 3,679,314; 3,870,629; 4,179,685), the detection of security threads and characteristics of security threads such as location, color (e.g., under normal and/or ultraviolet illumination), thread material construction, covert thread characteristics such as coatings, bar codes, microprinting, etc. Color detection techniques may employ color filters, colored lamps, and/or dichroic beamsplitters. Furthermore, optical sensing can be performed using ultraviolet light to detect reflected ultraviolet light and/or fluorescent light including detection of patterns of the same. Furthermore, optical sensing can be performed using infrared light including detection of patterns of the same.

Additionally, retrieved characteristic information can include magnetic characteristic information. A variety of currency characteristics can be measured using magnetic sensing. These include detection of locations of magnetic ink, detection of patterns of changes in magnetic flux (U.S. Pat. No. 3,280,974), patterns of vertical grid lines in the portrait area of bills (U.S. Pat. No. 3,870,629), the presence of a security thread (U.S. Pat. No. 5,151,607), thread location, thread metal content, thread material construction, thread magnetic characteristics, covert thread features such as coatings, bar codes, and microprinting, total amount of magnetizable material of a bill (U.S. Pat. No. 4,617,458), patterns from sensing the strength of magnetic fields along a bill (U.S. Pat. No. 4,593,184), and other patterns and counts from scanning different portions of the bill such as the area in which the denomination is written out (U.S. Pat. No. 4,356,473). Additionally, a magnetoresistive sensor or a plurality of such sensors including an array of magnetoresistive sensors may be employed to detect, for example, magnetic flux. Examples of magnetoresistive sensors are described in, for example, U.S. Pat. Nos. 5,119,025, 4,683,508, 4,413,296, 4,388,662, and 4,164,770. Another example of a magnetoresistive sensor that may be used is the Gradiometer available from NVE Nonvolatile Electronics, Inc., Eden Praire, MN. Additionally, other types of magnetic sensors may be employed for detecting magnetic flux such as Hall effect sensors and flux gates.

In addition to magnetic and optical sensing, other techniques of detecting characteristic information of currency include electrical conductivity sensing, capacitive sensing (U.S. Pat. No. 5,122,754 [watermark, security thread]; 3,764,899 [thickness]; 3,815,021 [dielectric properties]; 5,151,607 [security thread]), and mechanical sensing (U.S. Pat. No. 4,381,447 [limpness]; 4,255,651 [thickness]).

According to other embodiments of the present invention, three or more types of characteristics are retrieved from bills to be processed. These multiple types of characteristic information are used in various ways as described below to authenticate and/or denominate bills. Given sensors may be employed to detect multiple types of characteristic information. For example, an optical sensor may be employed both to generate scanned optical patterns but also to detect the presence, location, and/or color of security threads.

Referring now to FIGs. 6a-6c, there is shown a side view of one embodiment of a document authenticating and discriminating system according to the present invention, a top view of the embodiment of FIG. 6a along the direction 18B, and a top view of the embodiment of FIG. 6a along the direction 18C, respectively. An ultraviolet ("UV") light source 422 illuminates a document 424. Depending upon the characteristics of the document, ultraviolet light may be reflected off the document and/or fluorescent light may be emitted from the document. A detection system 426 is positioned so as to receive any light reflected or emitted toward it but not to receive any UV light directly from the light source 422. The detection system 426 comprises a UV sensor 428, a fluorescence sensor 430, filters, and a plastic housing. The light source 422 and the detection system 426 are both mounted to a printed circuit board 432. The document 424 is transported in the direction indicated by arrow A by a transport system (not shown). The document is transported over a transport plate 434 which has a rectangular opening 436 in it to permit passage of light to and from the document. An ultraviolet filter filters out visible light and permits UV light to be transmitted and hence to strike UV sensor 428. Similarly, a visible light filter filters out UV light and permits visible light to be transmitted and hence to strike fluorescence sensor 430. According to one embodiment a bill is identified as suspect if it fails to

reflect a high level of ultraviolet light or emits more than a predetermined level of visible light.

According to one embodiment of the present invention, the determination of whether the level of UV reflected off a document is high or low is made by sampling the output of the UV sensor at a number of intervals, averaging the readings, and comparing the average level with the predetermined high/low threshold. Alternatively, a comparison may be made by measuring the amount of UV light reflected at a number of locations on the bill and comparing these measurements with those obtained from genuine bills. Alternatively, the output of one or more UV sensors may be processed to generate one or more patterns of reflected UV light and these patterns may be compared to the patterns generated by genuine bills. Such a pattern generation and comparison technique may be performed by modifying an optical pattern technique such as that disclosed in United States Pat. No. 5,295,196. In a similar manner, the presence of fluorescence may be performed by sampling the output of the fluorescence sensor at a number of intervals.

The UV and fluorescence authentication test may be incorporated into various document handlers such as currency counters and/or currency denomination discriminators such as that disclosed in connection with FIG. 15 and U.S. Patent No. 5,295,196 incorporated herein by reference in its entirety. Likewise, the magnetic authentication tests described above may likewise be incorporated in such counters and/or discriminators.

Upon a bill failing one or more of the above tests, an appropriate error message may be displayed such as "Suspect Document U--" for failure of the UV reflection test, "Suspect Document -F-" for failure of the fluorescent test, "Suspect Document --M" for failure of the magnetic test, or some combination thereof when more than one test is failed (e.g., "Suspect Document UF-" for failure of both the UV reflection test and the fluorescent test).

New security features are being added to U.S. currency beginning with the 1996 series $100 bills. Subsequently, similar features will be added to other U.S. denominations such as the $50 bill, $20 bill, etc. Some of the new security features include the incorporation into the bills of security threads that fluoresce under

ultraviolet light. For example, the security threads in the 1996 series $100 bills emit a red glow when illuminated by ultraviolet. The color of light illuminated from security threads under ultraviolet light will vary by denomination, for example, with the $100 notes emitting red light and the $50 notes emitting, for example, blue light or purple light.

Additionally, the location of the thread within the bill can be used as a security feature. For example, the security threads in all $100 bills are located in the same position. Furthermore, the location of the security threads in other denominations will be the same by denomination and will vary among several denominations. For example, the location of security threads in $10s, $20s, $50, and $100 may all be distinct. Alternatively, the location may be the same in the $20s and the $100s but different from the location of the security threads in the $50s.

The ultraviolet system described above in connection with FIG. 18 may be modified to take advantage of this feature. Referring to FIG. 7, a bill 330 is shown indicating three possible locations 332a - 332c for security threads in genuine bills depending on the denomination of the bill. Fluorescent light detectors 334a - 334c are positioned over the possible acceptable locations of fluorescing security threads. In systems designed to accept bills fed in either the forward or the reverse direction, identical detectors are positioned over the same locations on each half of the bill. For example, sensors 334c are positioned a distance d_5 to the left and right of the center of the bill 330. Likewise, sensors 334b are positioned a distance d_6 to the left and right of the center of the bill 330 while sensors 334a are positioned a distance d_7 to the left and right of the center of the bill 330. Additional sensors may be added to cover additional possible thread locations.

These sensors may be designed to detect a particular color of light depending on their location. For example, say location 332b corresponds to the location of security threads in genuine $100 bills and location 332c corresponds to the location of security threads in genuine $50 bills. Furthermore, if the security threads in $100 bills emit red light under ultraviolet light excitation and the security threads in $50 bills emit blue light under ultraviolet light excitation, then sensor 334b may be particularly designed to detect red light and sensor 334c may be designed to detect blue light. Such sensors

may employ filters which pass red and blue light, respectfully, while screening out light of other frequencies. Accordingly, for example, sensor 334b will respond to a security thread located at location 332b that emits red light under ultraviolet light excitation but not to a security thread at location 332b that emits blue light.

In another embodiment, one or more sensors located at a given lateral position may detect light of a plurality of wavelengths. For example, suppose the location of security threads for both the $100 and the $20 bills is at location 332b and suppose threads in genuine $100 bills emit red light under ultraviolet excitation while threads in genuine $20 bills emit green light. One or more sensors located over location 332b such as sensor 334b are then used to detect both the presence of threads at location 332b and the emitted color. Accordingly, the denomination and/or genuineness of a bill can be determined and/or authenticated.

Likewise, one or more sensors located at a plurality of lateral position may detect light of the same or different wavelengths. For example, suppose the location of security threads for $100 bills is at location 332b and the location of security threads for $10 bills is at location 332a and suppose threads in both genuine $100 bills and genuine $10 bills emit red light under ultraviolet excitation. One or more sensors located over location 332b such as sensor 334b and one or more sensors located over location 332a such as sensor 334a are then used to detect both the presence of threads at locations 332b and 332a and the emitted color. In one embodiment the sensors may be designed to detect only red light. Alternatively, the sensors may be designed to detect a plurality of colors of light and provide an indication of the color that is detected. Accordingly, the denomination and/or genuineness of a bill can be determined and/or authenticated.

Sensors 334a - 334c may include separate sources of ultraviolet light or one or more separate ultraviolet light sources may be provided to illuminate the bill or portions of the bill, either on the same side of the bill as the sensors or on the opposite side of the bill. These sensors may be arranged along the same axis or, alternatively, may be staggered upstream and downstream relative to each other. These sensors may be arranged all on the same side of the bill or some on one side of the bill and some on the other. Alternatively, for one or more locations 332a - 332c sensors may be placed

on both sides of the bill. This dual sided embodiment would be beneficial in detecting counterfeits made by applying an appropriate fluorescing material on the surface of a bill. Alternatively, a combination of normal lighting and ultraviolet lighting may be employed but at different times to detect for the presence of a colored line applied to the surface of a bill visible in normal lighting. According to such an embodiment, no colored thread should be detected under normal lighting and an appropriate colored thread in an appropriate position must be detected under ultraviolet lighting.

Additionally, the authentication technique described above in connection with FIGs. 18 and 19 may be employed in areas where no fluorescing security threads might be located, for example, near the center of the bill, such that the detection of fluorescent light would indicate a counterfeit bill as would the absence of a high level of reflected ultraviolet light.

Alternatively or additionally, sensors may be employed to detect bills or security threads printed or coated with thermochromatic materials (materials that change color with a change in temperature). Examples of threads incorporating thermochromatic materials are described in U.S. Pat. No. 5,465,301 incorporated herein by reference. For example, a security thread may appear in one color at ambient temperatures under transmitted light and may appear in a second color or appear colorless at or above an activation temperature or vice versa. Alternatively, bills may be printed and/or coated with such thermochromatic materials. Such bills may or may not include security threads and any included security threads may or may not also be printed or coated with thermochromatic materials. To detect for the proper characteristics of bills containing such thermochromatic materials and/or containing threads employing such thermochromatic materials, the above described embodiments may be altered to scan a bill at different temperatures. For example, a bill could first be scanned at ambient temperatures, and then be transported downstream where the temperature of the bill is raised to or above an activation temperature and scanned again at the higher temperature. For example, FIG. 7 could be modified to employ two sets of pairs of sensors 334a-c, one set downstream of the other with the downstream sensors be located in a region where the temperature is evaluated relative to the temperature of the region where the first set of sensors are located. A bill

adjacent to the first and second sets of sensors 334a-c may be illuminated either with visible light or ultraviolet light (if the thermochromatic material contains materials whose fluorescent characteristics alter with changes in temperature). Accordingly, the presence of the appropriate color or absence of color may be detected for the different temperatures and the detected information may be used to authenticate and/or denominate the bill.

Alternatively, sensors 334a - 334c may be magnetic sensors designed to detect a variety of magnetic characteristic such as those described above. For example, sensors 334a - 334c may be magnetoresistive sensors as described above.

The magnetic characteristics of 1996 series $100 bills also incorporate additional security features. Referring to FIG. 8a, several areas of the bill 340 are printed using magnetic ink, such as areas A-K. Additionally, in some areas the strength of the magnetic field is stronger than it is in areas A-K. These strong areas of magnetics are indicated, for example, at 344a and 334b. Some areas, such as area 346 contain magnetic ink that is more easily detected by scanning the bill along one dimension of the bill than the other. For example, a strong magnetic field is detected by scanning over area 346 in the long or wide dimension of the bill 340 and a weak field is detected by scanning area 346 in the narrow dimension of the bill 340. The remaining areas of the bill are printed with non-magnetic ink.

Some of these magnetic characteristics vary by denomination. For example, in FIG. 8b, in a new series $50 note 350, areas A', B', C', E', F', G' and K' may be printed with magnetic ink and areas 354a and 354b may exhibit even stronger magnetic characteristics. Accordingly, the non-magnetic areas also vary relative to the $100 bill.

The use of magnetic ink in some areas of bills of one denomination and in other areas of bills of other denominations is referred to as magnetic zone printing. Additionally, magnetics are employ as a security feature by using ink exhibiting magnetic properties in some areas and ink that does not exhibit magnetic properties in adjacent areas wherein both the ink exhibiting and the ink not exhibiting magnetic properties appear visually the same. For example, the upper left-hand numerical 100 appears visually to be printed with the same ink. Nonetheless, the "10" are printed

with ink not exhibiting magnetic properties while the last "0" is printed with ink that does exhibit magnetic properties. For example, see area F of FIG. 8a.

Examples of arrangements of magnetic sensors that may be used to detect the above described magnetic characteristics are illustrated in FIGs. 10a, 10b, and 11. Additionally, the arrangements described above may also be employed such as those depicted in FIGs. 4, 6-10, 12, and 15. FIGs. 10a and 10b illustrate bills 360 and 361 being transported past magnetic sensors 364a-d and 366a-g in the narrow dimension of the bill. FIG. 11 illustrates bill 370 being transported past magnetic sensors 374a-c in the long dimension of the bill. FIGs. 10b and 11 illustrate a staggered arrangement of sensors. Magnetic scanning using these sensors may be performed in a manner similar to that described above in connection with optical scanning. For example, each sensor may be used to generate a magnetically scanned pattern such as that depicted in FIG. 14. Such patterns may be compared to stored master magnetic patterns. The scanning may be performed in conjunction with timing signals provided by an encoder such as described above in connection with optical scanning. Sensors 364, 366, and 374 may be magnetic sensors designed to detect a variety of magnetic characteristic such as those described above. These include detection of patterns of changes in magnetic flux, total amount of magnetizable material of a bill, and patterns from sensing the strength of magnetic fields along a bill. An additional type of magnetic detection system is described in U.S. Pat. No. 5,418,458. For example, sensors 364, 366, and 374 may be magnetoresistive sensors as described above. Additionally, other types of magnetic sensors may be employed of detecting magnetic flux such as Hall effect sensors and flux gates.

Alternatively, instead of generating scanned magnetic patterns, the presence or absence of magnetic ink in various areas may be detected and compared the stored master information coinciding with several areas where magnetic ink is expected and not expected on genuine bills of various denominations. For example, the detection of magnetic ink at area F is be expected for a $100 bill but might not be for a $50 bill and vice versa for area F'. See FIGs. 8a and 8b. Accordingly, the detected magnetic information may be used to determine the denomination of a bill and/or to authenticate that a bill which has been determined to have a given denomination using a different

test, such as via a comparison of an optically scanned pattern with master optical patterns, has the magnetic properties expected for that given denomination. Timing signals provided by an encoder such as described above in connection with optical scanning may be employed in detecting magnetic characteristics of specific areas of bills.

Additionally, for magnetic properties that are the same for all bills, such as the presence or absence of magnetic ink in a given location, such as the absence of magnetic ink in area 347 in FIGs. 8a and 8b, may be used as a general test to authenticate whether a given bill has the magnetic properties associated with genuine U.S. currency.

An example of scanning specific areas for the presence or absence of magnetic ink and denominating or authenticating bills based thereon may be understood with reference to FIGs. 9a and 9b. In FIGs. 9a and 9b, areas M_1 - M_{15} are scanned for the presence or absence of magnetic ink. For a 1996 series $100 bill as indicated in FIG. 9a, magnetic ink should be present at areas M_2, M_3, M_5, M_7, M_{12}, and M_{14} but not for the other areas. For a new series $50 bill as indicated in FIG. 9b, magnetic ink might be expected at areas M_1, M_6, M_8, M_9, and M_{13} but not for the other areas. Similarly for other denominations, magnetic ink would be expected in some areas but not others. By magnetically scanning a bill at areas M_1 - M_{15} and comparing the results with master magnetic information for each of several denominations, the denomination of the scanned billed may be determined. Alternatively, where the denomination of a bill has already be determined, the authenticity of the bill can be verified by magnetically scanning the bill at areas M_1 - M_{15} and comparing the scanned information to the master information associated with the predetermined denomination. If they sufficiently match, the bill passes the authentication test.

Alternatively, magnetic sensors 364a-d, 366a-g, and 374a-c may detect the magnitude of magnetic fields at various locations of a bill and perform bill authentication or denomination based thereon. For example, the strength of magnetic fields may be detected at areas J, 344a, and 348. See FIG. 8a. In a genuine $100 bill, no magnetic ink is present at area 348. One test to call a bill to be a $100 bill or authenticate that a bill is a $100 bill would be to compare the relative levels of

magnetic field strength detected at these areas. For example, a bill may be determined genuine if a greater signal is generated by scanning area 344a than area J which in turn is greater than for area 348. Alternatively, generated signals may be compared against expected ratios, for example, that the signal for area 344a is greater than 1.5 times the signal for area J. Alternatively, the signals generated by scanning various locations may be compared to reference signals associated with genuine bills for those locations.

Another denominating or authenticating technique may be understood with reference to area 346 of FIG. 8a. It will be recalled that for this area of a $100 bill a strong magnetic signal is generated when this area is scanned in the long dimension of the bill and a weak signal is generated when this area is scanned in the narrow dimension. Accordingly, the signals generated by sensors 364 and 374 for this area can be compared to each other and/or to different threshold levels to determine whether a particular bill being scanned has these properties. This information may be then used to assist in calling the denomination of the bill or authenticating a bill whose denomination has previously been determined.

The sensors of FIGs. 10, 10a, 10b, and 11 may be embodied as separate discrete sensors. Alternatively, two or more of these sensors may be embodied in the same scanhead or array structure. For example, FIG. 10c depicts the arrangement of FIG. 10a except that sensors 364a-d are arranged in a single scanhead 365. In a like manner, the sensors of FIGs. 10, 10b, and 11 may be arranged in one or more scanheads. For example, the staggered arrangement of sensors 366 depicted in FIG. 10b may comprise two scanheads, each comprising a linear array of sensors (FIG. 10d, scanheads 367a, 367b). For example sensors 366a-d may be arranged in a first scanhead and sensors 366e-g may be arranged in a second scanhead. Other arrangements are illustrated in FIGs. 10e and 10f which include scanheads 369 and 371a and 271b. These scanheads of multiple sensors may comprise, for example, magnetoresistive sensors as described above.

FIGs. 12-34 are flowcharts illustrating several methods for using optical, magnetic, and security thread information to denominate and authenticate bills. These methods may be employed with the various characteristic information detection techniques described above including, for example, those employing visible and

ultraviolet light and magnetics including, for example, those for detecting various characteristics of security threads.

FIG. 12 is a flowchart illustrating the steps performed in optically determining the denomination of a bill. At step 500, a bill is optically scanned and an optical pattern is generated. At step 502 the scanned optical pattern is compared to one or more stored master optical patterns. One or more master optical patterns are stored for each denomination that a system employing the method of FIG. 12 is designed to discriminate. At step 504 it is determined whether as a result of the comparison of step 502 the scanned optical pattern sufficiently matches one of the stored master optical patterns. For example, the comparison of patterns may yield a correlation number for each of the stored master patterns. To sufficiently match a master pattern, it may be required that the highest correlation number be greater than a threshold value. An example of such a pattern comparison method is described in more detail in U.S. Pat. No. 5,295,196 incorporated herein by reference. If the scanned pattern does not sufficiently match one of the stored master patterns, a no call code is generated at step 506. Otherwise, if the scanned pattern does sufficiently match one of the stored master patterns, the denomination associated with the matching master optical pattern is indicated as the denomination of the scanned bill at step 508.

FIG. 13 is a flowchart illustrating the steps performed in determining the denomination of a bill based on the location of a security thread. At step 510, a bill is scanned for the presence of a security thread. The presence of a security thread may be detected using a number of types of sensors such as optical sensors using transmitted and/or reflected light, magnetic sensors, and/or capacitive sensors. See, for example, U.S. Pat. Nos. 5,151,607 and 5,122,754. If a thread is not present as determined at step 512, a suspect code may be issued at step 514. This suspect code may indicate that no thread was detected if this level of detail is desirable. The lack of the presence of a thread resulting in a suspect code is particularly useful when all bills to be processed are expected to have a security thread therein. In other situations, the absence of a security thread may indicate that a scanned bill belongs to one or more denominations but not others. For example, assuming security threads are present in all genuine U.S. bills between $2 and $100 dollars, but not in genuine $1 bills, the

absence of a security thread may be used to indicate that a scanned bill is a $1 bill. According to one embodiment, where it is determined that no security thread is present, a bill is preliminary indicated to be a $1 bill. Preferably, some additional test is performed to confirm the denomination of the bill such as the performance of the optical denominating methods described above in FIG. 12. The optical denominating steps may be performed before or after the thread locating test. If at step 512 it is determined that a security thread is present, the location of the detected security thread is then compared with master thread locations associated with genuine bills at step 516. At step 518 it is determined whether as a result of the comparison at step 516 the detected thread location matches one of the stored master thread locations. If the detected thread location does not sufficiently match one of the stored master thread locations, an appropriate suspect code is generated at step 520. This suspect code may indicate that detected thread was not in an acceptable location if such information is desirable. Otherwise, if the detected thread location does sufficiently match one of the stored master thread locations, the denomination associated with the matching master thread location is indicated as the denomination of the scanned bill at step 522.

FIG. 14 is a flowchart illustrating the steps performed in determining the denomination of a bill based on the fluorescent color of a security thread. For example, as described above 1996 series $100 bills contain security threads which emit red light when illuminated with ultraviolet light. At step 524, a bill is illuminated with ultraviolet light. At step 526, the bill is scanned for the presence of a security thread and color of any fluorescent light emitted by a security thread that is present. The presence of a security thread may be detected as described above in connection with FIG. 13. Alternatively, the presence of a security thread may be detected before the bill is illuminated with ultraviolet light and scanned for fluorescent light. If a thread is not present as determined at step 528, an appropriate suspect code may be issued at step 530. The considerations discussed above in connection with FIG. 13 concerning genuine bills which do not contain security threads are applicable here as well. If at step 528 it is determined that a security thread is present, the color of any fluorescent light emitted by the detected security thread is then compared with master thread fluorescent colors associated with genuine bills at step 532. If at step 532, the detected

thread fluorescent light does not match one of the stored master thread fluorescent colors, an appropriate suspect code is generated at step 534. Otherwise, if the detected thread fluorescent color does sufficiently match one of the stored master thread fluorescent colors, the denomination associated with the matching master thread color is indicated as the denomination of the scanned bill at step 536. The sensors used to detect fluorescent light may be designed only to respond to light corresponding to an appropriate master color. This may be accomplished, for example, by employing light filters that permit only light having a frequency of a genuine color to reach a given sensor. Sensors such as those discussed in connection with FIGs. 6-7 may be employed to detect appropriate fluorescent thread colors.

According to another embodiment, the steps of FIG. 14 are employed but visible light rather than ultraviolet light is used to illuminate bills. Thus the denomination of bills is determined based on the color of security threads under visible light illumination.

FIG. 15 is a flowchart illustrating the steps performed in determining the denomination of a bill based on the location and fluorescent color of a security thread. FIG. 15 essentially combines the steps of FIGs. 13 and 14. At step 540, the bill is scanned for the presence, location, and fluorescent color of a security thread. The presence of a security thread may be detected as described above in connection with FIG. 13. If a thread is not present as determined at step 542, an appropriate suspect code may be issued at step 544. The considerations discussed above in connection with FIG. 13 concerning genuine bills which do not contain security threads are applicable here as well. If at step 542 it is determined that a security thread is present, the detected thread location is compared with master thread locations at step 546. If the location of the detected thread does not match a master thread location, an appropriate suspect code may be issued at step 548. If the location of the detected thread does match a master thread location, the scanned bill can be preliminary indicated to have the denomination associated with the matching thread location at step 550. Next at step 552 it is determined whether the color of any fluorescent light emitted by the detected security thread matches the master thread fluorescent color associated with a genuine bill of the denomination indicated at step 550. If at step 552,

the detected thread fluorescent light does not match the corresponding stored master thread fluorescent color for the preliminary indicated denomination, an appropriate suspect code is generated at step 554. Otherwise, if the detected thread fluorescent color does sufficiently match the stored master thread fluorescent color for the preliminary indicated denomination, at step 556 the scanned bill is indicated to be of the denomination indicated at step 550.

According to another embodiment, at step 540 visible light rather than ultraviolet light is used to illuminate bills in connection with the detection of the color of security threads. Thus at step 552 the detected color of security thread under visible light illumination is compared to master thread color information for genuine bill security threads illuminated by visible light.

While FIGs. 13-15 describe methods of evaluating a bill based on the location and color of security threads, other thread characteristics may alternatively or additionally be employed. Alternative thread-based characteristic information includes thread metal content, thread material construction, thread magnetic characteristics, and covert thread features such as thread coatings, bar codes, and microprinting. For example, the denomination of a bill may be microprinted on a security thread. These thread characteristics may be employed to authenticate and/or denominate bills and may be detected in a variety of ways such as optically or magnetically.

FIG. 16 is a flowchart illustrating the steps performed in magnetically determining the denomination of a bill. At step 558, a bill is magnetically scanned and one or more magnetic patterns are generated. Patterns generated may be, for example, patterns of magnetic field strength. Alternatively, instead of generating magnetically scanned patterns, a bill is magnetically scanned for the presence or absence of magnetic ink at one or more specific locations on the bill. Alternatively, instead of simply detecting whether magnetic ink is present at certain locations, the strength of magnetic fields may be measured at one or more locations on the bill. At step 560 the scanned magnetic information is compared to master magnetic information. One or more sets of master magnetic information are stored for each denomination that a system employing the methods of FIG. 16 is designed to discriminate. For example, where one or more scanned magnetic patterns are generated, such patterns are

compared to stored master magnetic patterns. Where, the presence or absence of magnetic ink is detected at various locations on a bill, this information is compared to the stored master magnetic information associated with the expected presence and absence of magnetic ink characteristics at these various locations for one or more denominations of genuine bills. Alternatively, measured field strength information can be compared to master field strength information. At step 562 it is determined whether as a result of the comparison of step 560 the scanned magnetic information sufficiently matches one of sets of stored master magnetic information. For example, the comparison of patterns may yield a correlation number for each of the stored master patterns. To sufficiently match a master pattern, it may be required that the highest correlation number be greater than a threshold value. An example of such a method as applied to optically generated patterns is described in more detail in U.S. Pat. No. 5,295,196 incorporated herein by reference. If the scanned magnetic information does not sufficiently match the stored master magnetic information, an appropriate suspect code is generated at step 564. Otherwise, if the scanned magnetic information does sufficiently match one of the sets of stored master magnetic information, the denomination associated with the matching set of master magnetic information is indicated as the denomination of the scanned bill at step 566.

FIG. 17 is a flowchart illustrating the steps performed in optically denominating a bill and authenticating the bill based on thread information. At step 568, a bill is optically denominated, for example, according to the methods described above in connection with FIG. 12. Provided the denomination of the bill is optically determined at step 568, the bill is then authenticated based on retrieved thread characteristic information such as the location and/or color of the security thread in the bill at step 570. The color of threads can be that under visible light illumination and/or ultraviolet illumination. The authentication step 570 may be performed, for example, according to the methods described in connection with FIGs. 13-15 and may alternatively or additionally utilize other thread characteristics described in connection therewith, e.g., covert features, magnetic content, etc. At step 570, however, the detected thread information such as location and/or color is only compared to master thread information such as location and/or color information associated with the

denomination determined in step 568. If the master thread information for the denomination indicated in step 568 match (step 572) the detected thread information for the bill under test, the bill is accepted (at step 576) as being a bill having the denomination determined in step 568. Otherwise, an appropriate suspect code is issued at step 574.

FIG. 18 is a flowchart illustrating the steps performed in denominating a bill based on thread information such as location and/or color information and optically authenticating the bill. At step 578, a bill is denominated based on thread information such as location and/or color information, for example, according to the methods described above in connection with FIGs. 13-15 and may alternatively or additionally utilize other thread characteristics described in connection therewith, e.g., covert features, magnetic content, etc. Provided the denomination of the bill is determined at step 578, the bill is then optically authenticated at step 580. The optical authentication step 580 may be performed, for example, according to the methods described in connection with FIG. 12. At step 580, however, the scanned optical pattern or information is only compared to master optical pattern or patterns or information associated with the denomination determined in step 578. If the master optical pattern or patterns or information for the denomination indicated in step 578 match (step 582) the scanned optical pattern or information for the bill under test, the bill is accepted (at step 586) as being a bill having the denomination determined in step 578. Otherwise, an appropriate suspect code is issued at step 584.

FIG. 19 is a flowchart illustrating the steps performed in optically denominating a bill and magnetically authenticating the bill. At step 588, a bill is optically denominated, for example, according to the methods described above in connection with FIG. 12. Provided the denomination of the bill is optically determined at step 588, the bill is then magnetically authenticated at step 590. The magnetic authentication step 590 may be performed, for example, according to the methods described in connection with in FIG. 16. At step 590, however, the detected magnetic information is only compared to master magnetic information associated with the denomination determined in step 588. If the master magnetic information for the denomination indicated in step 588 matches (step 592) the detected magnetic

information for the bill under test, the bill is accepted (at step 596) as being a bill having the denomination determined in step 588. Otherwise, an appropriate suspect code is issued at step 594.

FIG. 20 is a flowchart illustrating the steps performed in magnetically denominating a bill and optically authenticating the bill. At step 598, a bill is magnetically denominated, for example, according to the methods described above in connection with FIG. 16. Provided the denomination of the bill is magnetically determined at step 598, the bill is then optically authenticated at step 600. The optical authentication step 600 may be performed, for example, according to the methods described in connection with in FIG. 12. At step 600, however, the detected optical information (or pattern) is only compared to master optical information (or pattern or patterns) associated with the denomination determined in step 598. If the master optical information for the denomination indicated in step 598 matches (step 602) the detected optical information for the bill under test, the bill is accepted (at step 606) as being a bill having the denomination determined in step 598. Otherwise, an appropriate suspect code is issued at step 604.

FIG. 21 is a flowchart illustrating the steps performed in denominating a bill both optically and based on thread information such as location and/or color information. At step 608, a bill is optically denominated, for example, according to the methods described above in connection with FIG. 12. Provided the denomination of the bill is optically determined at step 608, the bill is then denominated based on thread information such as the location and/or color of the security thread in the bill at step 610. The denominating step 610 may be performed, for example, according to the methods described in connection with FIGs. 13-15 and may alternatively or additionally utilize other thread characteristics described in connection therewith, e.g., covert features, magnetic content, etc. At step 610, the denominating based on detected thread information such as location and/or color is performed independently of the results of the optical denominating step 608. At step 612, the denomination as determined optically is compared with the denomination as determined based on thread information such as location and/or color. If both optical and thread based denominating steps indicate the same denomination, the bill is accepted (at step 616) as

being a bill having the denomination determined in steps 608 and 610. Otherwise, an appropriate suspect code is issued at step 614. Alternatively, the order of steps 608 and 610 may be reversed such that the bill is first denominated based on thread information and then optically denominated.

FIG. 22 is a flowchart illustrating the steps performed in denominating a bill both optically and magnetically. At step 618, a bill is optically denominated, for example, according to the methods described above in connection with FIG. 12. Provided the denomination of the bill is optically determined at step 618, the bill is then denominated magnetically at step 620, for example, according to the methods described in connection with FIG. 16. At step 620, the magnetic denominating is performed independently of the results of the optical denominating step 618. At step 622, the denomination as determined optically is compared with the denomination as determined magnetically. If both optical and magnetic denominating steps indicate the same denomination, the bill is accepted (at step 626) as being a bill having the denomination determined in steps 618 and 620. Otherwise, an appropriate suspect code is issued at step 624. Alternatively, the order of steps 618 and 620 may be reversed such that the bill is first magnetically denominated and then optically denominated.

FIG. 23 is a flowchart illustrating the steps performed in denominating a bill both magnetically and based on thread information. At step 628, a bill is magnetically denominated, for example, according to the methods described above in connection with FIG. 16. Provided the denomination of the bill is magnetically determined at step 628, the bill is then denominated based on thread information such as the location and/or color of the security thread in the bill at step 630. The denominating step 630 may be performed, for example, according to the methods described in connection with FIGs. 13-15 and may alternatively or additionally utilize other thread characteristics described in connection therewith, e.g., covert features, magnetic content, etc. At step 630, the denominating based on detected thread characteristic information is performed independently of the results of the magnetic denominating step 628. At step 632, the denomination as determined magnetically is compared with the denomination as determined based on thread information. If both magnetic and

thread based denominating steps indicate the same denomination, the bill is accepted (at step 636) as being a bill having the denomination determined in steps 628 and 630. Otherwise, an appropriate suspect code is issued at step 634. Alternatively, the order of steps 628 and 630 may be reversed such that the bill is first denominated based on thread information and then magnetically denominated.

FIG. 24 is a flowchart illustrating the steps performed in denominating a bill optically, based on thread information, and magnetically. At step 638, a bill is optically denominated, for example, according to the methods described above in connection with FIG. 12. Provided the denomination of the bill is optically determined at step 638, the bill is then denominated based on thread information such as the location and/or color of the security thread in the bill at step 640. The denominating step 640 may be performed, for example, according to the methods described in connection with FIGs. 13-15 and may alternatively or additionally utilize other thread characteristics described in connection therewith, e.g., covert features, magnetic content, etc. At step 640, the denominating based on detected thread information is performed independently of the results of the optical denominating step 638. Provided the denomination of the bill is determined at step 640, the bill is then denominated magnetically at step 642, for example, according to the methods described in connection with FIG. 16. At step 642, the magnetic denominating is performed independently of the results of the denominating steps 638 and 640. At step 644, the denominations as determined optically, magnetically, and based on thread information are compared. If all denominating steps 638-642 indicate the same denomination, the bill is accepted (at step 648) as being a bill having the denomination determined in steps 638-642. Otherwise, an appropriate suspect code is issued at step 646. Alternatively, the order of steps 638 - 642 may be rearranged. For example, a bill may be first denominated optically, then be denominated magnetically, and finally be denominated based on thread information such as location and/or color. Alternatively, a bill may be first denominated magnetically, then be denominated optically, and finally be denominated based on thread information such as location and/or color. Alternatively, a bill may be first denominated magnetically, then be denominated based on thread information such as location and/or color, and finally be

denominated optically. Alternatively, a bill may be first denominated based on thread information such as location and/or color, and then be denominated magnetically, and finally be denominated optically. Alternatively, a bill may be first denominated based on thread information, and then be denominated optically, and finally be denominated magnetically.

FIG. 25 is a flowchart illustrating the steps performed in a method whereby a bill is denominated based on a first characteristic, then authenticated based on a second characteristic, and if the bill is authenticated, then the bill is denominated again based on the second characteristic. According to the flowchart of FIG. 25, at step 650, a bill is optically denominated, for example, according to the methods described above in connection with FIG. 12. Provided the denomination of the bill is optically determined at step 650, the bill is then magnetically authenticated at step 652. The magnetic authentication step 652 may be performed, for example, according to the methods described in connection with in FIG. 16. At step 652, however, the detected magnetic information is compared only to master magnetic information associated with the denomination determined in step 650. If the master magnetic information for the denomination indicated in step 650 does not sufficiently match (step 654) the detected magnetic information for the bill under test, an appropriate suspect code is issued at step 656. Otherwise, the bill is denominated again (at step 658) but this time using magnetic information. If the magnetically determined denomination does not match (step 660) the optically determined denomination, an appropriate error code is issued at step 662. If the magnetically determined denomination does match (step 660) the optically determined denomination, the denomination as determined at steps 650 and 658 is indicated as the denomination of the bill under test at step 664.

The method of FIG. 25 is advantageous in providing a high degree of certainty in the determination of the denomination of a bill while shortening processing time when a bill fails an earlier test. For example, at step 650 a bill is optically denominated. If the bill can not be called as a specific denomination under the optical test, a no call code is issued such as at step 506 in FIG. 12 and the denominating/authenticating process ends with respect to the bill. If the bill is successfully optically denominated, the bill is then authenticated based on magnetic

information at step 652. Processing time is saved at this step by comparing, the scanned magnetic information for the bill under test only with master magnetic information associated with the denomination as determined optically at step 650. If the scanned magnetic information does not sufficiently match the master magnetic information for that denomination, an appropriate suspect code is issued and the denominating/authenticating process ends with respect to the bill. If the bill successfully passes the authentication step 654, the bill is then denominated using the magnetic information. Here the scanned magnetic information is compared to master magnetic information for a number of denominations. It is then determined which denomination is associated with the master magnetic information that best matches the scanned magnetic information and this denomination is compared with the optically determined denomination to verify that they agree. For example, a bill may be optically determined to be a $100 bill. The magnetic information employed may be magnetic patterns similar to the optically generated patterns described above and in U.S. Pat. No. 5,295,196. At step 652, the scanned magnetic pattern is correlated against the master magnetic pattern or patterns associated with $100 bills. Assume, for example, that a correlation value of at least 850 is required to pass the authentication test. If the scanned magnetic pattern yields a correlation of 860 when compared to the master magnetic pattern or patterns associated with $100 bills, the bill then passes the authentication step 654. At this point, the bill is magnetically denominated independently of the results of the optical denominating step 650. This step ensures that the best match magnetically matches the best match optically. For example, if at step 658, the highest correlation is 860 which is associated with a $100 bill master magnetic pattern, then the magnetic denominating and optical denominating steps both point to a $100 bill and accordingly, the bill is indicated to be a $100 bill at step 664. However, if the highest correlation is 900 which is associated with a $20 bill master magnetic pattern, then the optically determined denomination and the magnetically determined denomination disagree and an appropriate error message is issued at step 662.

The method of FIG. 25 may be particularly useful in denominating and authenticating bills of higher denominations such as $20, $50, and $100 bills. The

higher value of these notes may make it desirable to undertake the additional denominating steps 658-664. The method of FIG. 25 could be modified so that if a bill were determined to be a $20, $50, or $100 at step 650 then the steps as indicated in FIG. 25 would be followed. However, if a bill were determined to be a $1, $2, $5, or $10 at step 650, then instead of magnetically denominating the bill at step 658, the bill could be immediately accepted such as in FIG. 19.

FIG. 26 is a flowchart illustrating the steps performed in a method whereby a bill is denominated based on a first characteristic, then authenticated based on a second characteristic, and if the bill fails the authentication test, then the bill is denominated again based on the second characteristic. According to the flowchart of FIG. 26, at step 666, a bill is optically denominated, for example, according to the methods described above in connection with FIG. 12. Provided the denomination of the bill is optically determined at step 666, the bill is then magnetically authenticated at step 668. The magnetic authentication step 668 may be performed, for example, according to the methods described in connection with in FIG. 16. At step 668, however, the detected magnetic information is only compared to master magnetic information associated with the denomination determined in step 666. If the master magnetic information for the denomination indicated in step 666 matches (step 670) the detected magnetic information for the bill under test, the bill is indicated (at step 672) to have the denomination as determined at step 666. Otherwise, the bill is denominated again (at step 674) but this time using magnetic information. If the detected magnetic information sufficiently matches (step 676) any of the stored master magnetic information, an appropriate error code is issued at step 678. Because the bill failed the test at step 670, if the scanned magnetic information matches any of the stored master magnetic information, the matching master magnetic information will be associated with a denomination other than the denomination determined optically at step 666. Accordingly, at step 678, the magnetically determined denomination differs from the optically determined denomination and an appropriate error code may be generated such as a no call code indicating that the optical and magnetic tests resulted in different denomination determinations thus preventing the discriminator from calling the denomination of the bill under test. Such an error might be indicative of a situation

where the bill under test is a genuine bill that had its optical or magnetic appearance altered, for example, where a genuine $1 bill was changed so that it appeared optically at least in part to be like a higher denomination bill such as a $20 bill. If the detected magnetic information does not match (step 676) any of the stored master magnetic information, an appropriate suspect code is issued at step 680. The error code at step 680 may indicate that the scanned bill does not match magnetically any of the stored master magnetic information associated with genuine bills.

The method of FIG. 26 is advantageous in that processing time is saved where a bill is determined to be genuine after passing two tests. Furthermore, when a bill fails the test at step 670, an additional test is performed to better define the suspect qualities of a bill which is rejected.

In FIGs. 25 and 26 the first characteristic is optical information and the second characteristic is magnetic information. Alternatively, the methods of FIGs. 25 and 26 may be performed with other combinations of characteristic information wherein the first and second characteristic information comprise a variety of characteristic information as described above such as magnetic, optical, color, and thread based information. Examples of such alternatives are discussed below in connection with FIGs. 27-31. Alternatively, the methods of FIGs. 25 and 26 may be performed utilizing first characteristic information to denominate a bill, then using second characteristic information to authenticate the bill and finally denominating the bill again using third characteristic information. Again the variety of characteristic information described above such as magnetic, optical, color, and thread based information may be employed in various combinations as first, second, and third characteristic information.

FIG. 27 is similar to FIG. 26 and is a flowchart illustrating the steps performed in a method whereby a bill is denominated based on a first characteristic, then authenticated based on a second characteristic, and if the bill fails the authentication test, then the bill is denominated again based on the second characteristic. According to the flowchart of FIG. 27, at step 682, a bill is denominated based on thread information such as location and/or color, for example, according to the methods described above in connection with FIGs. 13-15 and may alternatively or additionally

utilize other thread characteristics described in connection therewith, e.g., covert features, magnetic content, etc. Provided the denomination of the bill is determined at step 682, the bill is then magnetically authenticated at step 684. The magnetic authentication step 684 may be performed, for example, according to the methods described in connection with in FIG. 16. At step 684, however, the detected magnetic information is only compared to master magnetic information associated with the denomination determined in step 682. If the master magnetic information for the denomination indicated in step 682 matches (step 686) the detected magnetic information for the bill under test, the bill is accepted and indicated (at step 688) to have the denomination as determined at step 682. Otherwise, the bill is denominated again (at step 690) but this time using magnetic information. If the detected magnetic information sufficiently matches (step 692) any of the stored master magnetic information, an appropriate error code is issued at step 696. Because the bill failed the test at step 686, if the scanned magnetic information matches any of the stored master magnetic information, the matching master magnetic information will be associated with a denomination other than the denomination determined at step 682. Accordingly, at step 696, the magnetically determined denomination differs from the thread-based determined denomination and an appropriate error code may be generated such as a no call code indicating that the thread-based and magnetic tests resulted in different denomination determinations thus preventing the discriminator from calling the denomination of the bill under test. If the detected magnetic information does not match (step 692) any of the stored master magnetic information, an appropriate suspect code is issued at step 694. The error code at step 694 may indicate that the scanned bill does not match magnetically any of the stored master magnetic information associated with genuine bills.

FIG. 28 is also similar to FIG. 26 and is a flowchart illustrating the steps performed in a method whereby a bill is denominated based on a first characteristic, then authenticated based on a second characteristic, and if the bill fails the authentication test, then the bill is denominated again based on the second characteristic. According to the flowchart of FIG. 28, at step 698, a bill is optically denominated, for example, according to the methods described above in connection

with FIG. 12. Provided the denomination of the bill is determined at step 698, the bill is then authenticated based on thread information such as location and/or color at step 700. The authentication step 700 may be performed, for example, according to the methods described in connection with in FIGs. 13-15 and may alternatively or additionally utilize other thread characteristics described in connection therewith, e.g., covert features, magnetic content, etc. At step 700, however, the detected thread information is only compared to master thread information associated with the denomination determined in step 698. If the master thread information for the denomination indicated in step 698 matches (step 702) the detected thread information for the bill under test, the bill is accepted and indicated (at step 704) to have the denomination as determined at step 698. Otherwise, the bill is denominated again (at step 706) but this time using thread information such as location and/or color. If the detected thread information matches (step 708) any of the stored master thread information, an appropriate error code is issued at step 712. Because the bill failed the test at step 702, if the thread-based information matches any of the stored master thread information, the matching master thread information will be associated with a denomination other than the denomination determined at step 698. Accordingly, at step 712, the thread-based determined denomination differs from the optically determined denomination and an appropriate error code may be generated such as a no call code indicating that the thread-based and optical tests resulted in different denomination determinations thus preventing the discriminator from calling the denomination of the bill under test. If the detected thread information does not match (step 708) any of the stored master thread information, an appropriate suspect code is issued at step 710. The error code at step 710 may indicate that the thread characteristics of the scanned bill does not match any of the stored master thread information associated with genuine bills.

FIG. 29 is also similar to FIG. 26 and is a flowchart illustrating the steps performed in a method whereby a bill is denominated based on a first characteristic, then authenticated based on a second characteristic, and if the bill fails the authentication test, then the bill is denominated again based on the second characteristic. According to the flowchart of FIG. 29, at step 714, a bill is

magnetically denominated, for example, according to the methods described above in connection with FIG. 16. Provided the denomination of the bill is determined at step 714, the bill is then authenticated based on thread information such as location and/or color at step 716. The authentication step 716 may be performed, for example, according to the methods described in connection with in FIGs. 13-15 and may alternatively or additionally utilize other thread characteristics described in connection therewith, e.g., covert features, magnetic content, etc. At step 716, however, the detected thread information is only compared to master thread information associated with the denomination determined in step 714. If the master thread information for the denomination indicated in step 714 matches (step 718) the detected thread information for the bill under test, the bill is accepted and indicated (at step 720) to have the denomination as determined at step 714. Otherwise, the bill is denominated again (at step 722) but this time using thread information. If the detected thread information matches (step 724) any of the stored master thread information, an appropriate error code is issued at step 728. Because the bill failed the test at step 718, if the thread-based information matches any of the stored master thread information, the matching master thread information will be associated with a denomination other than the denomination determined at step 714. Accordingly, at step 728, the thread-based determined denomination differs from the magnetically determined denomination and an appropriate error code may be generated such as a no call code indicating that the thread-based and magnetic tests resulted in different denomination determinations thus preventing the discriminator from calling the denomination of the bill under test. If the detected thread information does not match (step 724) any of the stored master thread information, an appropriate suspect code is issued at step 726. The error code at step 726 may indicate that the thread characteristics of the scanned bill does not match any of the stored master thread information associated with genuine bills.

FIG. 30 is similar to FIG. 25 and is a flowchart illustrating the steps performed in a method whereby a bill is denominated based on a first characteristic, then authenticated based on a second characteristic, and if the bill is authenticated, then the bill is denominated again based on the second characteristic. According to the flowchart of FIG. 30, at step 730, a bill is magnetically denominated, for example,

according to the methods described above in connection with FIG. 16. Provided the denomination of the bill is magnetically determined at step 730, the bill is then optically authenticated at step 732. The optical authentication step 732 may be performed, for example, according to the methods described in connection with in FIG. 12. At step 732, however, the detected optical information is only compared to master optical information associated with the denomination determined in step 730. If the master optical information for the denomination indicated in step 730 does not sufficiently match (step 734) the detected optical information for the bill under test, an appropriate suspect code is issued at step 736. Otherwise, the bill is denominated again (at step 738) but this time using optical information. If the optically determined denomination does not match (step 740) the magnetically determined denomination, an appropriate error code is issued at step 742. If the optically determined denomination does match (step 740) the magnetically determined denomination, the denomination as determined at steps 730 and 738 is indicated as the denomination of the bill under test at step 744.

FIG. 31 is also similar to FIG. 25 and is a flowchart illustrating the steps performed in a method whereby a bill is denominated based on a first characteristic, then authenticated based on a second characteristic, and if the bill is authenticated, then the bill is denominated again based on the second characteristic. According to the flowchart of FIG. 31, at step 746, a bill is denominated based on thread information such as location and/or color, for example, according to the methods described above in connection with FIGs. 13-15 and may alternatively or additionally utilize other thread characteristics described in connection therewith, e.g., covert features, magnetic content, etc. Provided the denomination of the bill is determined at step 746, the bill is then optically authenticated at step 748. The optical authentication step 748 may be performed, for example, according to the methods described in connection with in FIG. 12. At step 748, however, the detected optical information is only compared to master optical information associated with the denomination determined in step 746. If the master optical information for the denomination indicated in step 746 does not sufficiently match (step 750) the detected optical information for the bill under test, an appropriate suspect code is issued at step 752. Otherwise, the bill is denominated

again (at step 754) but this time using optical information. If the optically determined denomination does not match (step 756) the thread-based determined denomination, an appropriate error code is issued at step 758. If the optically determined denomination does match (step 740) the thread-based determined denomination, the denomination as determined at steps 746 and 754 is indicated as the denomination of the bill under test at step 760. FIGs. 32 and 33 illustrate methods where for a bill to be accepted it is first denominated utilizing first characteristic information, then authenticated using second characteristic information, and finally authenticated again using third characteristic information.

According to the flowchart of FIG. 32, at step 762, a bill is optically denominated, for example, according to the methods described above in connection with FIG. 12. Provided the denomination of the bill is optically determined at step 762, the bill is then magnetically authenticated at step 764. The magnetic authentication step 764 may be performed, for example, according to the methods described in connection with in FIG. 16. At step 764, however, the detected magnetic information is only compared to master magnetic information associated with the denomination determined in step 762. If the master magnetic information for the denomination indicated in step 762 matches (step 766) the detected magnetic information for the bill under test, the bill is then authenticated based on thread information such as location and/or color at step 768. The authentication step 768 may be performed, for example, according to the methods described in connection with in FIGs. 13-15 and may alternatively or additionally utilize other thread characteristics described in connection therewith, e.g., covert features, magnetic content, etc. At step 768, however, the detected thread information is only compared to master thread information associated with the denomination determined in step 762. If the master thread information for the denomination indicated in step 762 matches (step 770) the detected thread information for the bill under test, the bill is accepted and indicated (at step 772) to have the denomination as determined at step 762. Otherwise, the bill is denominated again (at step 774) but this time using thread information. If the detected thread information matches (step 776) any of the stored master thread information, an appropriate error code is issued at step 778. Because the

bill failed the test at step 770, if the thread-based information matches any of the stored master thread information, the matching master thread information will be associated with a denomination other than the denomination determined at step 762. Accordingly, at step 778, the thread-based determined denomination differs from the optically determined denomination and an appropriate error code may be generated such as a no call code indicating that the thread-based and optical tests resulted in different denomination determinations thus preventing the discriminator from calling the denomination of the bill under test. If the detected thread information does not match (step 776) any of the stored master thread information, an appropriate suspect code is issued at step 780. The error code at step 780 may indicate that the thread characteristics of the scanned bill does not match any of the stored master thread information associated with genuine bills.

If at step 766 the master magnetic information for the denomination indicated in step 762 does not match the detected magnetic information for the bill under test, the bill is denominated again (at step 782) but this time using magnetic information. If the detected magnetic information sufficiently matches (step 784) any of the stored master magnetic information, an appropriate error code is issued at step 786. Because the bill failed the test at step 766, if the scanned magnetic information matches any of the stored master magnetic information, the matching master magnetic information will be associated with a denomination other than the denomination determined optically at step 762. Accordingly, at step 786, the magnetically determined denomination differs from the optically determined denomination and an appropriate error code may be generated such as a no call code indicating that the optical and magnetic tests resulted in different denomination determinations thus preventing the discriminator from calling the denomination of the bill under test. If the detected magnetic information does not match (step 784) any of the stored master magnetic information, an appropriate suspect code is issued at step 788. The error code at step 788 may indicate that the scanned bill does not match magnetically any of the stored master magnetic information associated with genuine bills.

According to the flowchart of FIG. 33, at step 782, a bill is optically denominated, for example, according to the methods described above in connection

with FIG. 12. Provided the denomination of the bill is determined at step 782, the bill is then authenticated based on thread information such as location and/or color at step 784. The authentication step 784 may be performed, for example, according to the methods described in connection with in FIGs. 13-15 and may alternatively or additionally utilize other thread characteristics described in connection therewith, e.g., covert features, magnetic content, etc. At step 784, however, the detected thread information is only compared to master thread information associated with the denomination determined in step 782. If the master thread information for the denomination indicated in step 782 matches (step 786) the detected thread information for the bill under test, the bill is then magnetically authenticated at step 788. The magnetic authentication step 788 may be performed, for example, according to the methods described in connection with in FIG. 16. At step 788, however, the detected magnetic information is only compared to master magnetic information associated with the denomination determined in step 782. If the master magnetic information for the denomination indicated in step 782 matches (step 790) the detected magnetic information for the bill under test, the bill is indicated (at step 791) to have the denomination as determined at step 782. Otherwise, the bill is denominated again (at step 792) but this time using magnetic information. If the detected magnetic information sufficiently matches (step 793) any of the stored master magnetic information, an appropriate error code is issued at step 794. Because the bill failed the test at step 790, if the scanned magnetic information matches any of the stored master magnetic information, the matching master magnetic information will be associated with a denomination other than the denomination determined optically at step 782. Accordingly, at step 794, the magnetically determined denomination differs from the optically determined denomination and an appropriate error code may be generated such as a no call code indicating that the optical and magnetic tests resulted in different denomination determinations thus preventing the discriminator from calling the denomination of the bill under test. If the detected magnetic information does not match (step 793) any of the stored master magnetic information, an appropriate suspect code is issued at step 795. The error code at step 795 may indicate that the scanned

bill does not match magnetically any of the stored master magnetic information associated with genuine bills.

If at step 786 the master thread information for the denomination indicated in step 782 does not match the detected thread information for the bill under test, the bill is denominated again (at step 796) but this time using thread information. If the detected thread information matches (step 797) any of the stored master thread information, an appropriate error code is issued at step 798. Because the bill failed the test at step 786, if the thread-based information matches any of the stored master thread information, the matching master thread information will be associated with a denomination other than the denomination determined at step 782. Accordingly, at step 798, the thread-based determined denomination differs from the optically determined denomination and an appropriate error code may be generated such as a no call code indicating that the thread-based and optical tests resulted in different denomination determinations thus preventing the discriminator from calling the denomination of the bill under test. If the detected thread information does not match (step 797) any of the stored master thread information, an appropriate suspect code is issued at step 799. The error code at step 799 may indicate that the thread characteristics of the scanned bill does not match any of the stored master thread information associated with genuine bills.

FIG. 34 illustrates a method where for a bill to be accepted it is first denominated utilizing first characteristic information, then authenticated using second characteristic information, then denominated using the second characteristic information, and finally authenticated using third characteristic information. According to the flowchart of FIG. 34, at step 800, a bill is magnetically denominated, for example, according to the methods described above in connection with FIG. 16. Provided the denomination of the bill is magnetically determined at step 800, the bill is then optically authenticated at step 802. The optical authentication step 802 may be performed, for example, according to the methods described in connection with in FIG. 12. At step 802, however, the detected optical information is only compared to master optical information associated with the denomination determined in step 800. If the master optical information for the denomination indicated in step 800 does not

sufficiently match (step 804) the detected optical information for the bill under test, an appropriate suspect code is issued at step 806. Otherwise, the bill is denominated again (at step 808) but this time using optical information. If the optically determined denomination does not match (step 810) the magnetically determined denomination, an appropriate error code is issued at step 812. If the optically determined denomination does match (step 810) the magnetically determined denomination, the bill is then authenticated based on thread information such as location and/or color at step 814. The authentication step 814 may be performed, for example, according to the methods described in connection with in FIGs. 13-15 and may alternatively or additionally utilize other thread characteristics described in connection therewith, e.g., covert features, magnetic content, etc. At step 814, however, the detected thread information is only compared to master thread information associated with the denomination determined in step 800. If the master thread information for the denomination indicated in step 800 matches (step 816) the detected thread information for the bill under test, the bill is accepted and indicated (at step 818) to have the denomination as determined at step 800. Otherwise, the bill is denominated again (at step 820) but this time using thread information. If the detected thread information matches (step 822) any of the stored master thread information, an appropriate error code is issued at step 824. Because the bill failed the test at step 816, if the thread-based information matches any of the stored master thread information, the matching master thread information will be associated with a denomination other than the denomination determined at step 800. Accordingly, at step 824, the thread-based determined denomination differs from the magnetically determined denomination and an appropriate error code may be generated such as a no call code indicating that the thread-based and magnetic tests resulted in different denomination determinations thus preventing the discriminator from calling the denomination of the bill under test. If the detected thread information does not match (step 822) any of the stored master thread information, an appropriate suspect code is issued at step 826. The error code at step 826 may indicate that the thread characteristics of the scanned bill does not match any of the stored master thread information associated with genuine bills.

FIGs. 32-34 provide examples of combinations of characteristic information employed as first, second, and third characteristic information. Alternatively, the methods of FIGs. 32-34 may be performed with other combinations of characteristic information wherein the first, second, and third characteristic information comprise a variety of characteristic information as described above such as magnetic, optical, color, and thread based information. For example, FIG. 32 illustrates an embodiment wherein the first characteristic information is optical information (step 762), the second characteristic information is magnetic information (steps 764, 766), and the third characteristic information is thread-based information (steps 768, 774). Likewise, FIG. 33 illustrates an embodiment wherein the first characteristic information is optical information (step 782), the second characteristic information is thread-based information (steps 784, 796), and the third characteristic information is magnetic information (steps 788, 792). FIG. 34 illustrates an embodiment wherein the first characteristic information is magnetic information (step 800), the second characteristic information is optical information (steps 802, 808), and the third characteristic information is thread-based information (steps 814, 820). In alternative embodiments of the methods of FIGs. 32-34, what is used as first, second, and third characteristic information is varied. For example, the first characteristic may be magnetic, the second characteristic may be thread-based, and the third characteristic may be optical. Alternatively, the first characteristic may be thread-based, the second characteristic may be magnetic, and the third characteristic may be optical. Alternatively, the first characteristic may be thread-based, the second characteristic may be optical, and the third characteristic may be magnetic.

In general, with respect to the methods described above in connection with FIGs. 12-34, the decision whether to authenticate a bill using one or more tests and/or to denominate a bill two or more times may be based on the value of the note as determined during the initial denominating step. For example, for a bill initially determined to be a $1 or $2 bill using a first denominating method, it may be desirable to immediately accept the bill or perform one authentication test such as illustrated in FIGs. 12-33. For bills initially determined to be of some immediate value such as $5 and $10 bills, it may be desirable to perform a second denominating step and/or an